Report of the First Advanced Superconducting Test Accelerator (ASTA) Program Advisory Committee Meeting

ASTA Program Advisory Committee

August 16, 2013

Contents

1 Introduction

This was the first meeting of the ASTA Program Advisory Committee. The Committee membership is given in Sec. 6. Committee members John Byrd and Georg Hoffstaetter were absent for this meeting. Marco Venturini (LBNL) and Richard York (MSU) kindly agreed to serve in their place.

The PAC meeting was held in parallel with the first ASTA Users' meeting. The agenda for the Users' meeting in given in Sec. 7. On the first day of the meeting, the PAC met for an hour during lunch, and also for about an hour after the end of the afternoon session. On the second day, the PAC met for about an hour for final discussions after the end of the Users' meeting. Subsequently, a brief closeout was held with the ASTA team and Fermilab management.

The charge for the PAC is given in Sec. 5. The PAC focused most of its deliberations on item 1 of the charge (the ASTA proposal), and developed a set of consensus recommendations which are presented below in Sec. 2. Individual PAC members provided comments on item 2 of the charge (status and plans), which are collected in Sec. 3. The experimental proposals described in the proposal and presented at the Users' meeting ranged from discussions of possible concepts for experiments to detailed experimental plans. Comments on some of these proposals from individual PAC members, as well as broader remarks on the experimental program, are presented in Sec. 4.

2 ASTA proposal

2.1 Findings

Fermilab has submitted a proposal to the Department of Energy to establish the Advanced Superconducting Test Accelerator, a world-leading facility for accelerator R&D. The facility is based on state-of-the-art, modern superconducting linac RF technology. It can support an extremely broad accelerator R&D program, ranging from high-energy physics to photon sciences to applications in many other accelerator stewardship areas. It serves several critical needs in Intensity Frontier accelerator physics, while helping to fulfill OHEP?s Stewardship role. It is cost-effective to complete and operate, and serves as a focal point for accelerator science education, not only for Fermilab, but for the nation.

Most of the facility infrastructure was developed as part of the ILC/SRF R&D Program, and later the American Recovery and Reinvestment Act (ARRA). To date, an investment of $74M has been made, including $18M of ARRA funding, representing ∼80% completion of the facility. When completed, the facility will have three experimental areas:

- Experimental Area 1: 50 MeV
- Experimental Area 2: 300-800 MeV
- Experimental Area 3: Integrated Optics Test Accelerator (IOTA) ring

In these areas, the facility is capable of housing 5-9 experiments running simultaneously. It will operate around-the-clock for 9 months of the year.

The proposal categorizes the experimental program at ASTA in terms of five major science thrusts:

- Intensity Frontier of Particle Physics
- Energy Frontier of Particle Physics
- Superconducting Accelerators for Science
- Novel Radiation Sources
- Stewardship and Applications

As of the time of the Users' meeting, 24 experimental proposals have been submitted for consideration, from a broad spectrum of proponents located at universities, national laboratories, and companies involved in accelerator development.

Fermilab submitted the ASTA proposal to DOE on Feb. 26, 2013. The scientific program was reviewed on Mar. 8, 2013, and the rest of the proposal will be reviewed on Oct. 21, 2013.

Comments from the PAC on details of the proposal, followed by a consensus set of recommendations which are responsive to charge item 1, are provided in the next two subsections.

2.2 Comments

2.2.1 General comments

ASTA will be a unique test facility employing SRF technology. The R&D in SRF and demonstration of stable and reliable operation of high gradient SRF cryomodules with an intense electron beam should be one of the priorities, at least in the earlier phases of the facility development.

Present plans include operation with trains of up to 3000 bunches, at 5 Hz pulse repetition rate. The committee notes that very few experiments take advantage of this bunch structure. Indeed, most experiments will benefit from using a higher pulse repetition rate and fewer bunches per pulse (perhaps, just one bunch). Thus, it is advisable to consider other pulse formats that may better meet users' demands.

To highlight the uniqueness of ASTA, it is also advisable to give higher priority to experiments that can only be done using an SRF linac, as opposed to experiments that can be done elsewhere. ASTA with 800 MeV beam energy will most likely have better beam parameters than other beam test facilities that operate at lower beam energies. It is advisable to highlight this aspect too.

A subset of proposals for IOTA look rather strong. However, IOTA seems to be loosely connected to the ASTA linac program. The committee advises that the proposal should show tighter links between the ASTA linac program and IOTA, both on technical grounds, and to exploit the complementarity of skills of the personnel and the unique position of Fermilab as an accelerator development laboratory.

The committee notes that the benefit of the research at ASTA outlined in the proposal, using existing ASTA systems, experienced people and well-tested infrastructure, is very high relative to the incremental cost required to carry out the research.

2.2.2 Specific comments

- The first cryomodule is generally referred to as ACC1. However, in one figure (p. 209) it is named CM1 and elsewhere it is called "2nd CM".
- A couple of typos: search for the word "principle", often erroneously used to mean "principal". On p. 99 replace "accelerator" → "accelerate". On p. 98 "This can done ..." → "This can be done ...".
- NML (new muon lab) is never defined. (see page 205). Even though it is not a new muon lab, just calling it NML is confusing to the uninitiated.
- Section 5.0: Cite important experiments which make use of the high peak brightness or average brightness, and which could not be done at the other facilities because of the lower brightness. Also: the figure of merit plotted in Fig. 1 is the normalized brightness. But one could argue that the geometric brightness is a more relevant parameter. Since this scales like γ^2, higher energy facilities have an advantage here. The text should point out why the normalized brightness is chosen for the figure of merit.

- Section 6.0: No quantitative information is provided on the transverse emittance, or on the expected capabilities of the RFBT to provide a flat beam. It would be good to include the expected emittance and coupling ratio.
- Section 7.2 (IOTA): The goal is to demonstrate single-particle aspects of the design (large tune spreads), but the ultimate payoff is in control of collective effects. The proposal does not explain quantitatively what the expected benefit would be in terms of high current operation, how this would be tested, etc. Specifics should be given here, instead of just referring to future research (p. 51 bottom)
- Section 7.3.1: (p 63)-several typos, sloppy editing: eq 6 should be have $a_p \to a_s$; after (9), ϵ should be rms transverse emittance. IOTA parameters in Table 1 differ from those given in sec. 7.2. The OSC discussion would benefit from less equations and more figures showing results of simulations, tolerance requirements, etc.
- 7.3.2.4 needs some editing: duplication is present.

2.3 Recommendations

The committee recommends that the ASTA proposal be re-structured to emphasize the three major accelerator science and technology areas which are its main focus:

- *Superconducting RF system development.* This work supports both the intensity frontier (for example, through its application to Project X) and the energy frontier (for example, through its application to the ILC). The effort addresses key unsettled issues in this technology development, and is a natural conclusion to work already started. There is a big leverage to the existing investment in these systems, and lessons that will be learned during completion and commissioning of the SCRF systems are a major part of the technology development R&D.
- *Experiments at the IOTA storage ring.* This work supports the intensity frontier (through its application to high current proton accelerators). The outlined program to develop machine understanding using electron beams as probes, followed by performance demonstrations in the space-charge dominated regime using proton beams, is an excellent approach. Pioneering work at IOTA in nonlinear lattices would have wide applications for all future accelerators.
- *Development of methods for emittance transformations/exchanges.* This work supports advanced acceleration experiments and applications for light sources. It is a natural extension of the pioneering flat-beam and emittance exchange work done at A0. The flexibility afforded by the ASTA beam lines allows a major broadening of this work with numerous important applications.

The committee recommends that the proposal should highlight these major areas, in the executive summary, in the proposal's introduction, and in a restructured chapter 7, in which the details of work in these areas are fleshed out.

A facility focused on these major areas can also do many other things (for example, in the areas of accelerator stewardship, and the development of radiation sources). This is reflected in the many concepts for experiments, and some detailed proposals, which have been put forward from users. However, since many of these are less well developed than the major thrusts, the committee suggests concentrating on the major areas in chapter 7, and covering the other, less developed but promising, areas in an appendix.

A final recommendation is the following. In the text, whenever possible, specific applications and benefits of the results of proposed experiments or technology developments should be given. For example, for IOTA, how will the current limit in proton machines be increased if the nonlinear lattice allows a large tune spread in the beam? How much could the lifetime of a high energy collider be increased if the optical stochastic cooling experiment is successful?

3 ASTA status and plans

3.1 Findings

At the time of the Users' meeting, the ASTA photo-injector was being commissioned. The first photoelectrons from the gun were observed on June 20. The second ILC-style 8-cavity cryomodule ("CM2") is installed downstream from the injector. It is not yet cold, but RF commissioning is planned to start soon. The IOTA ring components are being delivered.

By the end of FY13, it is planned to start commissioning of the 50 MeV beam lines and Experimental Area 1. Some of the experiments slated for Experimental Area 1 will also be installed. RF commissioning of the first ASTA 8-cavity cryomodule will start.

During FY14, the first experiments at 50 MeV will begin. RF commissioning of the first ASTA 8-cavity cryomodule will be completed. The 300 MeV beamline to the dump will be installed. IOTA construction will continue.

During FY15, experiments will continue with 50 MeV beam. The cryomodule will be commissioned with beam, and the first experiments at 300 MeV will begin. IOTA construction will be completed, and installation will begin.

3.2 Comments

- The committee understands that the facility plans will evolve and develop as more experiments are planned and executed.
- Consistent with the recommendation in the previous section to highlight 3 main research areas (SCRF technology development, IOTA, emittance exchange), it would be good to give appropriate emphasis also to the third thrust (emittance exchange) in the facility development plan and schedule.
- The timeline on page 43 looks reasonable but some things could be shuffled around. The stage 1 plan looks good. Finishing the first cryomodule followed by some diagnostics at the end of the linac allow for commissioning the linac as quickly as possible. Installing IOTA next is a good idea. After that, the two new cryomodules are installed, followed by the H^- injector for IOTA. The last two might be reversed, but that decision should be made after seeing how things went. As much local talent as possible should be used.
- The presentation clarity can be improved if elements of Chapter 10 are copied into Chapter 1, *e.g.*, Figures 2-5 on pages 224-227.
- However, these figures only show "end points" and do not show parallel activities: *e.g.*, is IOTA installation/testing without beam going on in parallel with Stage 1.1 and 1.2 activities? A Gantt Chart is needed to better communicate plans. There is simply not enough detail in Chapter 10 to answer the question in the charge as to whether the "plans (are) technically sound and achievable", although certainly they seem plausible. The same point can be made for the question regarding the "balance of construction and installation activities and needs of first experimental studies." Creating a resource loaded schedule will not only better communicate your intent, and therefore garner productive critique, but also will likely identify issues/conflicts the project team may not yet be aware of.
- An unfortunate artifact of the ILC heritage is lack of true CW SRF operation. CW SRF linacs are key element of future FELs. An analysis of how/how much/and when a CW system could be implemented is recommended.

4 ASTA experimental program

4.1 Findings

There are 24 experiments described in Chapter 7 of the ASTA proposal. Of these, seven have also been described in individual proposal documents, in a format which specifies the experimental goals, required beam parameters, personnel involved, experimental techniques to be used, and expected outcomes. In addition, as of the time of the Users' meeting, 5 new experiments, not included in the ASTA proposal, had been submitted in the form of individual proposal documents.

At the Users' meeting, many of the experimental proposals were described. Additional areas of possible experimental exploration with the ASTA facility were discussed at the meeting, although generally these concepts were not sufficiently well developed to be considered experimental proposals.

4.2 Comments

4.2.1 General comments

There is a very wide range in the degree of development of the ASTA experimental proposals. The format developed for the individual proposal documents is a good one, and all experimenters should be required to submit their proposal using this format. Once all proposals are documented using this format, it will be much easier to identify the strengths and weaknesses of each proposal, to provide meaningful specific advice on feasibility, and to make comparisons.

4.2.2 Specific comments

- Quadrupole pickups will be needed for a direct measurement of space charge in IOTA.
- Electron-cloud effects for protons in the IOTA vacuum chamber should be checked.
- In the description of the IOTA experiment, it is mentioned (p. 56) that the T-section has tight requirements on phase advance errors (0.02). This seems small compared to the space-charge tune shift that one would hope to achieve when injecting the ring with a proton beam. Could this compromise the ability to demonstrate the virtues of the Integrable Optics lattice to accept large tune shifts?
- Also related to IOTA, it is mentioned (p. 52) that the T-sections should be achromats. Does this mean that chromatic sextupoles are needed? What would be their impact on the dynamics?
- Emphasis in the experimental program should play to Fermilab's strengths. Beam dynamics is a traditional research area at FNAL; plasma and dielectric wakefield accelerators are not. It may be a very long time before the latter are useful for HEP. On the other hand, learning how to contend with a space charge tune shift of order 1 would be a game changer. Even if it does not work, it would be the beginning of a significant and wonderful new effort in nonlinear dynamics. Right now, tracking is the main tool and it is often dull, dreadful work. Seeing some canonical transformations that actually yielded useful new results would be beautiful science.
- The laser electron gamma source (LEGS) was decommissioned at BNL back in 2007. Before spending too much effort on a new gamma ray source, it would be important to check the user community.
- To avoid Brownian motion, it is very important to develop a clear set of research priorities and widely communicate them, especially as they will be modified due to enhanced information. The committee suggests keeping small number of categories, *e.g.*, the three 3 major focus areas suggested in Sec. 2, and mapping as much as possible every experiment into one of these thrusts. This approach will help in keeping a coherent focus and communicating it to the user community.

- Priority should be given to experiments that use the ASTA facility as "proof-of-principle" test bed, with successful tests (*e.g.* Compton Source) being "spun off" to their own "stand-alone" facility, if there is a sufficient user community.

5 Charge for the First ASTA PAC Meeting

The ASTA Program Advisory Committee is asked to assess and provide advice on the following topics:

1. ASTA Proposal Proposal for Accelerator R&D User's Facility at ASTA has been submitted to DOE and will be reviewed in the Fall of 2013. Is the Proposal well-formulated? Are any modifications advisable? Is the Science Case strong and are there ways that it can be strengthened? Should any newly submitted experiments be added?

2. ASTA status and plans ASTA team has recently achieved 1st photoelectrons from the gun and is focused on a number of high level goals for the remainder of FY13, FY14 and FY15. Are these plans technically sound and achievable? Do they properly balance the construction and installation activities and the needs of the first experimental studies? Could the plans be modified/optimized in order to more firmly establish ASTA as a leading R&D facility?

3. Experimental studies at ASTA There are a number of previously proposed and newly proposed experiments with ASTA beams. ASTA PAC is asked to evaluate the scientific merit of the proposed experiments and EOI's, evaluate the feasibility of the proposed experiments in relation to the ASTA beam and facility capabilities, and advise on optimal order and priority of the studies.

6 Committee Membership

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1st Advanced Superconducting Test Accelerator (ASTA) User's Meeting and PAC Meeting

Tuesday 23 July 2013

Introduction: Vladimir Shiltsev - (08:45-09:00)

ASTA Overview & Proposal Process: Vladimir Shiltsev - (09:00-09:20)

Beamline Configuration & Capabilities: Philippe Piot - (09:20-09:40)

IOTA Ring Configuration & Capabilities: Alex Valishev - Curia II (2nd floor, west side) (09:40-10:00)

Laser Systems Available & Forseen: Jinhao Ruan - (10:00-10:15)

Standard Electron-beam Diagnostics: Nathan Eddy - Curia II (2nd floor, west side) (10:15-10:30)

Beamline Mechanical Assembly & Vacuum requirements: Lucy Nobrega - (10:30-10:45)

Commissioning Activities & Recent Results: Elvin Harms - (11:15-11:35)

LLRF R: Brian Chase - Curia II (2nd floor, west side) (11:35-11:55)

A Highly-Brilliant X-ray Source based on Channeling Radiation: Charles Brau - (11:55-12:15)

Bunch Compressor & Temporal Slicer: Jayakar Thangaraj - (12:15-12:30)

Integrable Optics experiments: Sergei Nagaitsev - (13:30-13:50)

Halo suppresion by nonlinear decoherence: Stephen Webb - Curia II (2nd floor, west side) (13:50-14:05)

New design principles for beam halo suppression in hadron accelerators at the intensity frontier -- proposed use of the Synergia framework to develop an experimental plan for the IOTA ring: David Bruhwiler - (14:05-14:15)

On two proposed IOTA experiments: Integrable optics with space charge and wave-function measurements: Slava Danilov - (14:15-14:30)

Can you hear the shape of a drum?: Bela Erdelyi - (14:30-14:45)

Nonlinear Integrable Optics at the University of Maryland: Kiersten Ruisard - (14:45-15:00)

IOTA: Moses Chung - (15:00-15:15)

Discussion - (15:15-15:30)

Seminar: Eric Colby - (16:00-17:00)

Demonstration of high-power high-gradient SRF caryomodule w intense beams: Nikolay Solyak - (17:00-17:20)

Ultra-Stable Operation of SRF Linacs with Beam-Based Feedback: G. Huang - (17:20-17:35)

Interest from CSU (AI-based control of SCRF linacs): Auralee Morin - (17:35-17:50)

Discussion: Session 4: SRF/LLRF R&D - (17:50-18:00)

No Host Dinner : Pal Joey's-Batavia - (18:30-19:00)

Wednesday 24 July 2013

Tagged Photon Beam for Detector R : David Christian - (08:30-08:45)

Electron Beam Shaping and High Gradient, High Transformer Ratio Acceleration in a Dielectric Tube: Evgenya Simakov - Curia II (2nd floor, west side) (08:45-09:00)

Flat-Beam-Driven Dielectric-Wakefield Acceleration in slab Structures: Francois Lemery - Curia II (2nd floor, west side) (09:00-09:15)

Nano-Crystal Channeling Acceleration Experiment: Young Min Shin - Curia II (2nd floor, west side) (09:15-09:30)

Miniaturized Magnetic Undulator for X-ray Generation: Alexandra Garraud - Curia II (2nd floor, west side) (09:30-09:45)

Inverse Compton Scattering: Alex Murokh - Curia II (2nd floor, west side) (09:45-10:00)

Application of Inverse Compton Scattering: C. Ugalde - Curia II (2nd floor, west side) (10:00-10:15)

Production of Narrow Band gamma-rays: Chuck Ankenbrandt - Curia II (2nd floor, west side) (10:15-10:30)

Feasability of an XUV FEL Oscillator: Alex Lumpkin - (10:45-11:00)

Laser-induced Microbunching Studies: Alex Lumpkin - (11:00-11:15)

Beam Dechirper using Corrugated Pipe : Marco Venturini - (11:15-11:30)

Beam dechirper (silencer) using dielectric- waveguides: Sergey Antipov - (11:30-11:45)

Beam -beam kicker for an electron-ion collider: Y. Zhang - Curia II (2nd floor, west side) (11:45-12:00)

Demonstration Technique to Generate & Manipulate Ultra-low Emittance for Future Hard X-ray FELs: John Lewellen - (12:00-12:15)

DISCUSSION - Curia II (2nd floor, west side) (12:15-12:30)

ASTA Facility Tour: Trasnportation provided - Pick up in front of Wilson Hall - (13:30-14:30)